N74-10255

Paper No. 65

SOLAR IMAGE, CORONA AND RADIATION SIMULATIONS FOR THE APOLLO TELESCOPE MOUNT DISPLAYS OF THE SKYLAB SIMULATOR

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ABSTRACT

An objective of the Skylab Simulator is to train crews to point the solar telescopes of the Apollo Telescope Mount and to recognize, select and record solar activity of scientific interest. The simulator utilizes Hydrogen-alpha photography and correlated simulations of predicted emissions from regions of the solar spectrum, much of which is not detectable from earth, as data sources for the displays of the simulator's control and display panel. Analog servoes with digital feedback enables precision pointing at selected solar features viewed on the visual displays. This paper is about the development and utilization of solar activity simulations from a visual aspect.

INTRODUCTION

The Skylab Orbital Assembly was launched in May of 1973 and is manned by a thoroughly prepared crew. This preparation was obtained through exhaustive academic and procedural training at several locations using various devices, including the Skylab Simulator. Many different types of experiments are being conducted aboard the Skylab spacecraft which pertain to earth resources, to the functions of the spacecraft and to the effects of space on man. Astronomical experiments using the ATM (Apollo Telescope Mount) are being performed in the visible, the near and far ultraviolet and in the soft and hard X-ray regions of the sun. The ATM is the first manned orbiting solar observatory.

Simulation of the ATM in the Skylab Simulator enabled the training of the astronauts in pointing the solar telescopes properly and in coalignment procedures between experiments, as well as in the exercise of judgment in the selection of features of scientific interest. The purpose of the solar experiments is, in part, the collection of data which may establish spatial and temporal correlation between solar activity at different wavelengths and bandwidths, both on and off disc. Because of the sparsity of correlated data, the simulations had to be based upon the scientific knowledge and judgment of the Principal Investigators and their colleagues. As more knowledge was gained it was put into immediate use in the production of more authentic solar image simula-

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tions.

This discussion concerns itself with the ATM simulation design philosophy from a visual aspect and with the production of highly accurate films depicting the sun in H-alpha (Hydrogen-Alpha), in simulated XUV (Extreme Ultra Violet), in simulated X-ray and with the production of precision slides showing solar corona simulations and white light solar discs. Radio noise and simulated radiations are also mentioned to illustrate the extent of simulated correlation.

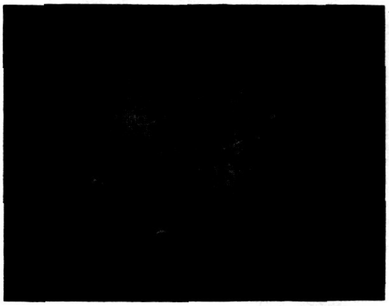
BACKGROUND

Along with digital readouts for X-ray and ultraviolet, and the History Plotter for X-ray and radio noise, the visual displays for the ATM consists of two television monitors and one X-ray cathode ray tube. The television monitors provide independently selectable solar video scenes in H-alpha, XUV, white light corona and XUV slit, that is, white light solar disc with XUV slit. There are two H-alpha telescopes operating at the same frequency and bandwidth. The zoom ratio of the televised optical leg of each telescope is 5:1. However, the maximum video field of view for H-alpha 1 is only 22 arc minutes while that of H-alpha 2 is 35 arc minutes. Since the diameter of the sun as viewed from earth subtends about 32.1 arc minutes the entire sun cannot be seen in H-alpha 1. The video fields of view in XUV, white light corona and XUV slit are 60 arc minutes, 1.5 to 4.5 solar radii and three arc minutes, respectively. The field displayed on the X-ray cathode ray tube is a 48 by 48 arc minute matrix.

HYDROGEN-ALPHA

Solar radiation is mostly characteristic of hydrogen because of the abundance of this element on the sun. H-alpha, the 6562.8 Angstrom light emission arising from transitions between the second and third electron orbits of the hydrogen atom, is especially strong and only slightly attenuated by the atmosphere of the earth. For this reason, the sun may be viewed in H-alpha from earth (Figure 1a). The narrow band H-alpha filters reveal finely structured detail of the chromosphere of the sun. Readily observable solar features are sunspots, plages, flares, and filaments. The image quality of the sun in H-alpha as viewed from earth is dependent upon the "seeing" conditions. Since the H-alpha telescope in the ATM cluster is operated above the atmosphere of the earth the seeing exceeds that viewed from earth.

One of the purposes of these telescopes during the Skylab mission is to identify solar features which can be examined with other telescopes operating in the UV and X-ray regions of the solar spectrum. Another purpose is to enable precise positioning of instruments coaligned with H-alpha, particularly instruments with narrow fields of view, such as the S055A UV Polychromator Spectroheliometer experiment and the S082B XUV Spectrograph experiment, both of which rely upon the H-alpha 1 video display



·Figure 1a The Sun in H-alpha

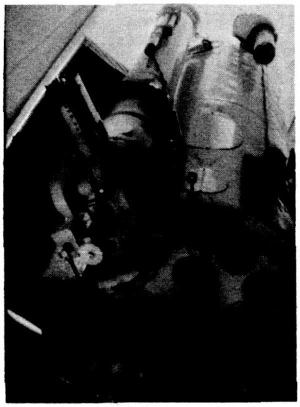


Figure 1b Big Bear Telescope

for guidance. The H-alpha 2 display is used as a backup pointing system. In addition, photographs taken with the H-alpha 1 film camera will be used after each mission to correlate the emissions recorded by the other instruments with the features recognized in H-alpha because previous earth-based H-alpha experience provides an excellent datum for the other experiments.

H-ALPHA SIMULATION

The H-alpha system on a whole had to meet more difficult requirements so H-alpha will be discussed in some detail. Much of what is about to be said about the H-alpha simulation design philosophy applies also to the other systems. The function of the H-alpha displays in the Skylab Simulator is the same as that in the spacecraft. For this reason the emphasis has been placed upon obtaining good quality imagery of the sun in H-alpha with as complete a complement of solar phenomena as obtainable. Basically, the system utilizes 35-mm film in an electro-optical projection system. The projected image is viewed by a television camera and displayed at the ATM console. The rationale for this approach was arrived at after considerable study.

Rationale

Most of the available H-alpha imagery was recorded on film. Some had been collected on video tape because video recordings have the advantage of an order of magnitude greater dynamic range than film. However, to utilize video tapes in H-alpha simulation would require too complex a design concept - this is especially so because of the zoom in/zoom out requirement at the control and display panel. After due consideration, real time simulation of computer generated H-alpha imagery was judged to be beyond the current state of the art. Thus it was clear that the best choice would be to use H-alpha photography as the data source. To confirm the feasibility of an approach utilizing film as the image source, a vidicon telecine chain with zoom capability was breadboarded early in 1969 by Mr. Ralph Payne of Johnson Space Center prior to the writing of specifications. It demonstrated the practicability of this concept. Interestingly, although film was not specified as the image storage medium, all respondents to the request for proposals proposed only this medium.

Photography

Existing H-alpha photography was deficient for simulation use in several respects: unreliable frame-to-frame image registry, truncated solar discs, variable exposures, low resolution, short duration sequences and low frame rates. But even with good registry, whole solar discs, uniform exposures, specified resolution and sufficiently long sequences, none of the available solar patrol films contained sun images in H-alpha at the same bandpass as that of the spacecraft telescopes.

Because of these deficiencies, the successful offerer, the Link Division of Singer-General Precision, Inc., purchased an 8.6 inch Boller and Chivens solar vacuum telescope with the same bandpass at H-alpha as the ATM telescopes. It was especially fabricated and equipped with an Acme 35-mm camera for the H-alpha data collection. It is installed on the side of an existing larger telescope at the Big Bear Solar Observatory of the California Institute of Technology (Figure 1b), under the direction of Dr. Zirin. The optical quality of the system at H-alpha was demonstrated to have a modulation transfer of 65 percent at the specified spatial frequency of two arc seconds. An automatic exposure system compensates for changes in the sun's luminance and a photoelectric guider system maintains the telescope at sun-center even when the main spar is off center. The camera film is Kodak Type SO-392 Solar Patrol Film.

To ensure precise film positioning, the camera, 35-mm printer and 35-mm projector, each uses similar pin register systems precise to three ten thousands of an inch, which together with the control of film perforation pitch to five ten thousandths of an inch on the negative and positive estar base films, assures excellent image placement.

Initial filming sequences were taken at one frame per ten seconds during quiet periods and one frame per second during flare activity. This provided the crews with an undesired flare onset cue which was eliminated in subsequent sequences by going to a constant rate of one frame per five seconds.

Monitoring positive prints are made from the negatives to less stringent quality standards than those required for the simulation prints. These monitoring prints are reviewed for the selection of four-hour training sessions of reasonably consistent image quality and containing activity of interest to the Observing Program Instructors, who are the representatives of the Principal Investigators. Once a selection is made a script print is laid out for correlating X-ray and XUV films to H-alpha. A simulation quality H-alpha print reel on Kodak Type 2430 film is then produced for the image projection system of the simulator.

Sensitometry

Sensitometry is now discussed because of its relative importance. The intensity range of the sun's chromosphere in H-alpha is relatively short thus making tonal differences difficult to distinguish. The negative film is processed to a gamma of three to expand this range thereby enhancing subtle differences in the solar activity. The range is further expanded by processing the positive print to a gamma of one and a half, resulting in a product gamma of four and a half. The product gamma is the gamma of the negative times the gamma of the positive, where gamma is the ratio of density to the logarithm of intensity, or more practically, the ratio of density to the logarithm of exposure. Efforts were made to place all areas of concern on the straight line portion of the H&D (Hurter and Driffield) curves to take full advantage of the linear film responses (Figures 2a and 2b). The required product gamma was arrived at experimentally since the film input requirement is dependent upon the electro-optical equipment of the simulator.

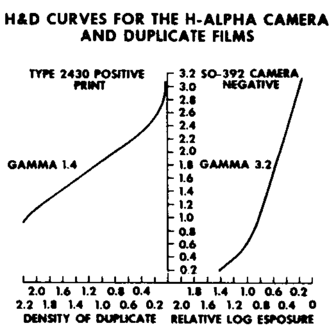


Figure 2a H&D Curves

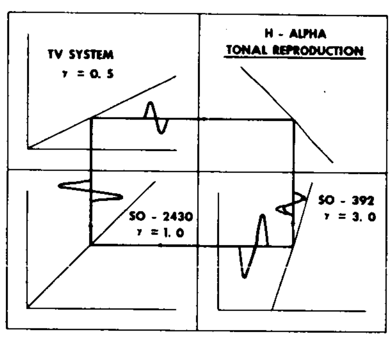


Figure 2b H-alpha Tonal Reproduction

Image Evaluation

The capability of a system to resolve fine detail can be predicted with some certainty even without taking all variables into consideration. By using a spatial frequency of 58 lp/mm representative of a 2 arc second image resolution throughout, the MTF (Modulation Transfer Factor) may be computed by way of contrast ratio once the MTF of the telescope, the camera film, the printer and the print film is known. The telescope optical system was designed to yield an optical transfer factor of 57 percent. Utilizing a sinusoidal MTF pattern of varying spatial frequency including the required 58 lp/mm, the camera negatives were experimentally found to have an amplitude of 40 percent and in like manner the print film was found to have an amplitude of 75 percent. With a test target of 1000:1 contrast ratio the printing MTF was found to be 97 percent. With these values, H-alpha positive print image resolution capability can then be predicted.

By operating on the straight line portion of the H&D curves density is equal to the product of gamma times the logarithm of exposure:

$$D = \gamma \log E \ .$$

The maximum less minimum density difference is proportional to the logarithm of the ratio of maximum to minimum exposure:

$$D_{max} - D_{min} \propto \log E_{max} / E_{min} \ .$$

This ratio is the contrast ratio of the exposure:

$$C_e = E_{max} / E_{min} \ .$$

Also, transmittance of a recorded image is inversely proportional to the antilogarithm of density,

$$T \propto 1 / \log^{-1} D \ ,$$

and thus the contrast ratio of the image is equal to the ratio of maximum to minimum transmittance:

$$C_i = T_{max} / T_{min} \ .$$

The modulation of the image is equal to the ratio of the difference to the sum of the maximum and minimum transmittance:

$$M = (T_{max} - T_{min}) / (T_{max} + T_{min}) \ .$$

Knowing this, contrast ratio in terms of modulation and vice versa can be determined.

From the preceeding, it can be shown that the logarithm of the contrast ratio of the recorded image is equal to the product of gamma times the logarithm of the contrast ratio of the exposure:

$$\log C_i = \gamma \log C_e \ ,$$

or

$$C_i = C_e^{\gamma} \ .$$

Remembering from above that the required product gamma was found experimentally, once the gamma of the camera film is determined the gamma of the print film is controlled to give the desired product gamma:

$$\gamma_p = \gamma_d / \gamma_c .$$

Now then, the exposure modulation is the product of the modulation of the telescope times that of the camera film:

$$M_e = M_t M_c .$$

The contrast ratio of the camera film exposure is equal to the ratio of one plus exposure modulation to one minus exposure modulation:

$$C_e = (1 + M_e) / (1 - M_e) .$$

The contrast ratio of the camera film image is equal to the contrast ratio of the camera film exposure to the predetermined gamma power:

$$C_i = C_e^{\gamma_c} .$$

The modulation of the camera film image is then equal to the ratio of the image contrast ratio minus one to image contrast ratio plus one:

$$M_i = (C_i - 1) / (C_i + 1) .$$

The product of this modulation times the modulation of the print film times the modulation of the printer is the modulation of the exposure of the print film:

$$M_e = M_i M_f M_p .$$

The contrast ratio of the print film exposure is then calculated:

$$C_e = (1 + M_e) / (1 - M_e) .$$

The film is developed to the controlled gamma to obtain the contrast ratio of the print image:

$$C_i = C_e^{\gamma_p} .$$

The modulation of the print image can then be calculated using this contrast ratio:

$$M_i = (C_i - 1) / (C_i + 1) .$$

Image Generation System

Now we can discuss the H-alpha image generation system through to the video displays. The raster format and scan rates are the same as in the spacecraft as is the simulated television downlink to Mission Control Center. A single H-alpha image centered in the film gate is projected through a dual optical system mounted upon a granite optical bench onto the photocathodes of two vidicon cameras. The image is optically split into H-alpha 1 and H-alpha 2 and, to ensure precise tracking, the X-Y excursion and roll capabilities are common to both images. Movable reticles are provided in each optical leg. Analog servoes with digital feedback enables precision pointing at selected solar features viewed on the visual displays. The table on which the lens is mounted is driven in X and Y translation by a lead-screw drive in a linear relation of inches of travel to image excursion in arc minutes.

A transformation program determines the image translation associated with the H-alpha scene by computing the direction cosines of the line of sight to the center of the sun in the frame of reference associated with the image and scales it to meet the requirements of the image translation servoes (Direction cosines differ for each experiment because of misalignments relative to the ATM canister). Small angle approximations are used in defining the transformations between experiment and canister frames of reference. Direction cosines of the canister are evaluated by the attitude control system. Another transformation program generates drive signals to the roll prisms by using canister frame components of the solar spin axis.

The response and resolution capabilities of the system is sufficient to display the effects of pointing accuracies, experiment misalignment and cluster vehicle jitter in compliance with pointing control requirements. The display system X-Y servo resolution for all servoes is as tabulated with monitor fields of view in arc minutes, monitor resolution in arc seconds per element, servo resolution in arc seconds per bit, servo excursion in inches and servo word in bits:

Exp.	Mon.FOV	Mon.Res.	Servo Res.	Servo Exc.	Servo Word
H-alpha 1	22 to 4.4	0.31	0.30	0.8063	14
H-alpha 2	35 to 7	0.47	0.30	0.8063	14
X-Ray	48	3.36	1.52	0.7150	12
WLC	144.45	10.11	6.08	0.8087	11
XUV Slit	3.0	0.21	0.17	0.7171	14
XUV Mon.	60	4.2	2.74	0.9381	11

Conveniently, the servo excursion for H-alpha can be and is deliberately limited when the solar scene leaves the video field of view and is replaced by a dark scene. This approach is also used on the other displays with the exception of the white light coronagraph display.

In the typical servo a variable bit word representing desired position is the input to an arithmetic processor which determines the difference between the actual shaft position as an output from a 14-bit shaft encoder and the position provided by the computer. This difference is weighted and transferred to D/A converters. The difference consists of 8 linear bits, overflow and a sine bit. The overflow bit drives the servo amplifier at maximum rate by applying 28 volts to the servo motor. The linear bits cause a variable rate to be applied to the motor. An auxiliary circuit processes the sine bit to determine servo rotation direction.

S055A UV SCANNING POLYCHROMATOR SPECTROHELIOMETER

This instrument is used for photometric UV observations of the solar atmosphere near and above active and quiet regions on the solar disc. The experiment is operated in one of two modes. In the Mirror Raster Mode the primary telescope mirror is rastered in two axes to cover a region five arc minutes by five arc minutes, while the spectrometer grating remains stationary. This provides telemetry data for reconstruction of monochromatic ultraviolet spectroheliograms of the solar region. Up to seven simultaneous spectroheliograms of different wavelengths may be reconstructed through use of any of seven detectors. In the Grating Scan Mode the telescope mirror remains fixed on a five arc second by five arc second feature of interest while the grating is rotated to scan the entire operating spectrum past one of the photomultiplier detectors. The crew may select the mode of operation, spectral line (or lines) to be observed and detector (or detectors) to employ.

S055A SIMULATION

The solar UV intensity is simulated by software data describing a solar disc with nominal background intensity and circular areas of desired size, location and intensity superimposed on the disc. There is a separate solar model for each training sequence derived by tracing outlines of simulated S082B XUV active regions displayed on the simulator's television monitor. From each tracing a three dimensional software model is programmed. In addition, the size and intensity of three selected areas vary as a function of time. Selected spectral lines are programmed in the simulator, which together with randomly generated spectral line simulations make up the desired spectral scanning region. The crew views a digital readout of simulated Detector No. 1 or Detector No. 3 outputs on the Intensity Data Display. For training in collaboration with the flight controllers, these simulations are transmitted as simulated telemetry from the Skylab Simulator, as is data from the other experiment and spacecraft simulations.

S056 EXTREME UV AND X-RAY TELESCOPE

S056 is comprised of two individual and independently operated instruments. An X-Ray Telescope provides filtergrams on film of the solar image in five bandwidths from 5 to 33 Angstroms. The other instrument, an X-Ray Event Analyzer, consists of a Beryllium-window and an Aluminum-window proportional counter subsystem. Each proportional counter produces outputs proportional to the intensity of the detected energy. Pulse-height analyzers sort these outputs into six energy levels in one channel and four energy levels in the other. These data are then available for telemetry or display on the counters or the History Plotter of the control and display panel of the ATM.

S056 SIMULATION

There is no visual simulation of the X-Ray Telescope except for selected filter, frames remaining and other such indicators typical of all experiment simulations necessary for training in procedures.

The source data for the X-Ray Event Analyzer is the Solrad 9 X-Ray Memory Data (Figure 3a) from the Naval Research Laboratory for the time period of the selected training session. Solrad 9

SOLRAD X-RAY DATA

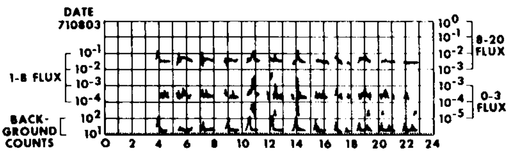


Figure 3a Solrad 9 X-Ray Memory Data

data is processed as Aluminum and Beryllium counts logarithmically and utilized as pulse-height analyzer output simulations. These data are stored and released throughout the training session to Monitor Counters 2 and 3, simulated telemetry and to the History Plotter. Initially, the simulated intensity was increased as a function of location to account for the South Atlantic Anomaly, but this effect was found to be trivial so its simulation was discontinued.

RADIO NOISE BURST MONITOR

A C-Band Radio Noise Burst Monitoring System aboard the spacecraft is capable of receiving solar electromagnetic radiation in the 5 GHz frequency range and indicating the radiation's relative intensity. The outputs from the RNBM (Radio Noise Burst Monitor) drive the History Plotter, the RNBM meter and the flare detector.

RNBM SIMULATION

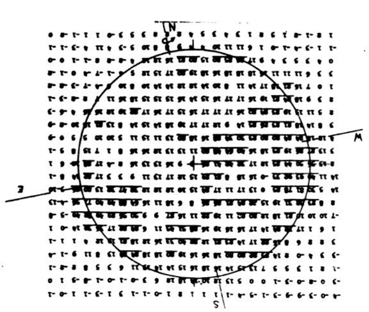
Solar radio noise data at 6 cm are collected as daily sequences, processed and stored by NOAA at Boulder, Colorado, on magnetic tapes. These tapes are processed at JSC through a modified existing SPAN data reduction program to output IBM compatible data tapes. Sequences temporally correlated with the training sessions selected are stored on magnetic disc and utilized throughout the session as a function of time.

S054 X-RAY SPECTROGRAPHIC TELESCOPE

This instrument, which is sensitive to wavelengths between 3 and 60 Angstroms, produces high resolution images that are photographically recorded. As an aid to the crew in aligning the telescope a real-time X-Ray Image display is provided. An X-ray image of the sun is formed on a thin scintillator and coupled to an image dissector tube by a fibre optic faceplate to convert it to a photon image. The photocathode of the Image Dissector converts the photon image into an electron image. This image is scanned sequentially point-by-point over a 48 by 48 arc minute matrix during a one second scan time. The output is a string of variable height pulses proportional to intensity which is gated through and to the Image Intensity Counter for display as a three-digit readout. The intensity output is converted to an analog signal to intensity modulate the X-Ray Image display trace. A Photomultiplier System detects X-rays which are produced as a series of pulses for high energy X-rays and a dc signal for low energy X-rays. The former is processed through an eight-level pulse height analyzer and telemetered to earth while the latter is routed to the flare detection system and the automatic camera exposure duration control.

S054 SIMULATION

Large positive H-alpha transparencies are made containing the basic H-alpha background and active flare regions during a particular training sequence. Solrad 9 (Figure 3a) data is used to provide flare onset cues which, along with the H-alpha monitor-



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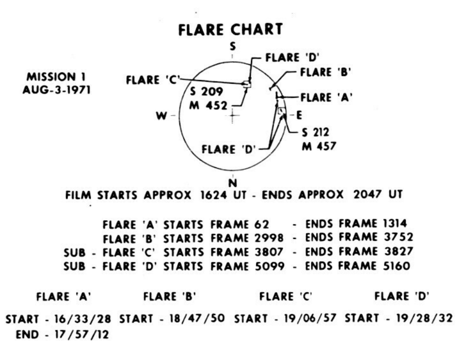

Figure 3b Stanford Radio Map   Figure 3c Flare Chart

ing print, is used to prepare a script coordinating X-ray flare activity with the selected sequence. A spectroheliogram (Figure 3b) within the same period is used to compile a coarse contour map of brightness levels on an overlay. From analyzed H-alpha pictures, fine intensity contour maps are prepared on other overlays. Individually categorized stencils are prepared for each contour. Using H-alpha basic background picture and spectroheliogram stencils a negative X-ray artwork is rendered and the artwork is photographed as a positive image. In like fashion artwork is rendered and photographed for each active flare and for significant changes in location and shape of flares. The basic X-ray positive transparency is photographed for the entire sequence to produce a session length negative film. The taking film is then exposed again, but this time for each selected flare scene (Figure 3c) at the time and for a duration determined by the script. During this dual exposure, intensity is varied for flare animation. From the X-ray master negative made with accurately positioned imagery, a simulation quality positive print (Figure 4a)

Figure 4a X-Ray Simulation

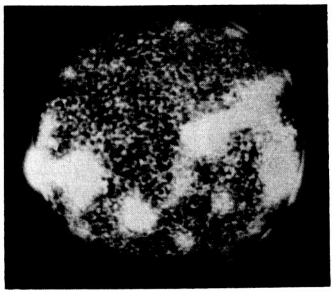

Figure 4b XUV Simulation

reel is produced for use in the simulator's electro-optical chain. The projected image produces a video image at a slow scan rate of 48 lines per second. This output is digitized and used as though it were an image dissector output to produce a 48 by 48 arc minute matrix of simulated X-ray image on the X-Ray Image display.

Solrad 9 (Figure 3a) data is scaled and stored on disc for each training session and released as a function of time. After processing and provided with random noise the output drives the Image Intensity Counter, simulated telemetry and the Photomultiplier Counter as an antilogarithmic function of intensity. The South Atlantic Anomaly was found to affect only the Photomultiplier output. The simulation has been altered to create this condition. The intensity versus photomultiplier curves provided by Dr. Zombeck, former Senior Scientist at American Science & Engineering, Inc., were approximated as a logarithmic relationship. The short dynamic range of film did not permit use of the X-ray simulation graphics as an Image Intensity Counter source. The point-by-point correlation with the X-Ray Image display was not considered essential for effective training before the first manned mission. During the mission it was generally found that there wasn't much to be seen on the X-Ray Image display although the Image Intensity Counter indicated that the system was working.

S082B XUV MONITOR AND SPECTROGRAPH

An XUV Monitor telescope rigidly attached to the Spectrograph telescope is used to observe the video image of the full solar disc in the 170 to 550 Angstrom range. This is done through conversion of the XUV image to white light and viewing it with a low-light level television camera. Its purpose is to produce real-time video pictures of the sun extending beyond the limb into the corona and to point the Spectrograph to features of interest. A seven-position sensitivity control permits camera sensitivity reduction in the event excessive input illumination is experienced by the camera. In the event of saturation a grid discharge switch is used to restore the camera to normal. An integrate switch increases camera sensitivity by gating target sweep off. When the integrate switch is released the camera output is the first single frame of information flashed onto the display monitor. It is only used when there is insufficient illumination for the camera. Picture intensity increases with the duration of time that the switch is held down. The Spectrograph, which includes an imaging system, is used to photographically record line spectra of small selected areas on and off disc and across the limb using a 2 by 60 arc second slit in two overlapping wavelengths extending from 970 to 3940 Angstroms. A Pointing Reference Subsystem in the same housing views the image of the sun which is formed at the spectrograph entrance slit by the primary mirror with an image dissector tube video camera. This subsystem generates either a video image in white light of the 3 arc minute area presented to the slit or a signal representative of limb to fiducial (the origin of reference) mark distance.

S082B SIMULATION

A simulated 304 Angstrom negative is produced by using a calcium K-line photograph combined with texture screens and utilizing photographic masking, exposure and development techniques. The basic XUV positive transparency is produced by combining modified X-ray negatives with the simulated 304 Angstrom negative. For flare scenes, XUV overlays, artwork and positive transparencies are produced in the same way that the X-ray flare scenes were made. The final XUV master negative is also produced by using the multiple exposure technique. A simulation quality positive print (Figure 4b) reel is produced for use in the electro-optical chain of the simulator. The displayed video field is 60 arc minutes. The grid discharge and integrate controls operate the same as in the real world. The sensitivity control is simulated by adjusting the gain and the pedestal of the video signal in opposite directions through a D/A converter.

Full white light solar disc photographs are taken every half hour during H-alpha photography at the Big Bear Solar Observatory (Figure 1b) with a Hasselblad camera mounted on the spar to the right of the H-alpha telescope. Hourly photographs of the white light sun for selected sequences are used to produce precision glass slides. During processing care is taken to enhance limb detail using dodging and bleaching techniques. In the absence of suitable white light solar disc photographs, simulations are produced from H-alpha photography by the Aero Service Corporation. Machined slide holders provide positional registry to an accuracy of one ten thousandths of an inch in a precision two by two inch dual carousel slide projector. An optical system is used to project a 3-arc minute segment of the white light solar disc image from the projector onto the television camera faceplate.

S052 WHITE LIGHT CORONAGRAPH EXPERIMENT

This instrument is an externally occulted WLC (White Light Coronagraph) designed to photograph the solar corona in the visible region with a field of view of 1.5 to 6 solar radii. A television camera similar to that of the XUV Monitor experiment enables visual observation of the corona as an aid in determining opportune times for photography, for monitoring particulate contamination surrounding the ATM and in providing ATM pointing capability backup. The video field of view is 1.5 to 4.5 solar radii. To prevent damage to the video camera from direct sunlight, a mirror which routes the image to the television camera reroutes it to the film camera instead when pointing angles exceed five arc minutes off sun center. A pointing error sensor system detects the external occulting disk location on the objective lens aperture. Its output is to present pointing error information thus providing an inflight fine pointing capability. An internal occulting disk provides internal alignment capability for the coronagraph.

S052 SIMULATION

Generally one corona simulation is provided for each training session selected. A few corona simulations are provided with additional slides depicting static simulations of the corona with contaminants and with transients or the effects of transients in the corona scene.

To determine what the corona should look like for any specific day an indepth study of the sun is made for a period covering thirteen days before and after the selected day. H-alpha photographs and K-coronameter plots (Figure 5a) for each of those days are studied. A sketch of the sun is prepared showing the location of sun spots and filaments for the selected day and where they would appear during the preceding and succeeding days. A three-dimensional model (Figure 5b) is constructed based upon plots for the thirteen days under study. The K-coronameter data are intensity plots taken around the sun at one and a half solar radii. From this study an accurate sketch of a solar corona for the selected day is compiled and submitted to the Principal Investigator, Dr. MacQueen, at the High Altitude Observatory, for

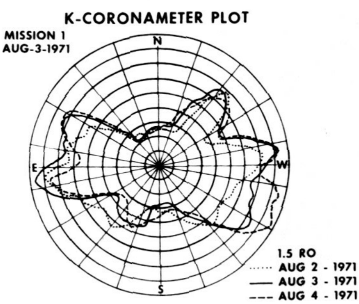

Figure 5a K-Coronameter Plot

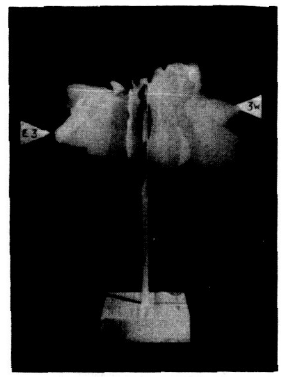

Figure 5b K-Coronameter Model

evaluation. If necessary, suitable changes are made and artwork of the simulated corona is rendered as a negative image. Overlays and double exposure techniques are used to provide transient and contaminant effects.

A positive photograph of the final rendition (Figure 5c) is also submitted to the Principal Investigator and colleagues for

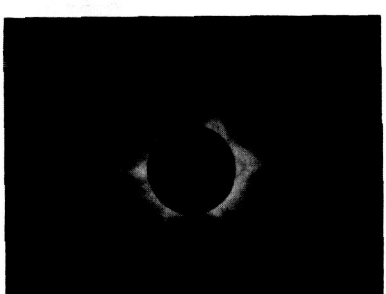

Figure 5c Corona Simulation

comments and approval. A properly scaled and positioned positive image on a precision slide is prepared for use in the electro-optical system of the simulator. It also uses a precision dual carousel slide projector. However, this system differs from the other in that the corona is projected onto a screen in the optical path which is then viewed by a standard television camera.

In addition, this system utilizes a separate optical leg to project auxiliary lighting into the main optical path. This is to simulate scattered light brightening at the edge of an occulting disc with pylon, as would be caused by pointing the canister off sun center.

Whenever the canister is pointed more than five arc minutes off sun center or when an aperture door open command is given, video is removed from the display monitor as though the scene were rerouted to the film camera instead of to the television camera. In the event of simulated malfunction, camera tube damage is simulated by displaying a white screen.

CONCLUDING REMARKS

The correlation of simulated emissions to earth-based H-alpha photography were in effect predictions of the anticipated correlation. Confidence was high that the correlation would hold particularly because the Observing Program Instructors had been using the simulator to develop observing programs for the Skylab missions. In general, the simulated correlation proved to be a reasonable assumption. The high fidelity simulations provided to the crews resulted in a high transfer of learning from the simulator to the spacecraft.